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Seagle-1, A new man-portable thermal imager

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ABSTRACT

This paper presents the design and performance of Chung Shan Institute of Science and Technology (CSIST) newest man-portable infrared imaging system, the **Seagle-1.**

The thermal imager is designed for day and night long-range observation and forward reconnaissance and surveillance applications. The camera system achieves an NETD =0.067K at 30 Hz frame rate with f/1.8 optics (300K background). The design and performance of the 256x244 PtSi infrared camera will be described in this paper.

KEYWORDS: platinum silicide, infrared , stirling mincooler

1. INTRODUCTION

The thermal imager system incorporates a number of advanced features to achieve lower power, compact size, and high performance. The sensor assembly is a 256x244 MWIR Platinum Silicide schottky barrier staring FPA, integrated to a low power high reliability stirling minicooler , some of the system features include : lightweight, f/1.8 100mm telescope internal 2.5" LCD min-monitor or external video output RS-170, and low power electronics. The nonuniformity calibration values are programmed at the factory and require no additional recalculation in the field. This feature offers significant saving in space and power. The system operates from standard internal battery or external power. Operation time by using the internal rechargeable Ni-MH battery is 3 hours. This system is quiet, rugged, reliable, easily maintainable, and affordable. Because of the compact size, low power consumption, and high performance, Seagle-1 is well suitable for portable applications.

2. CAMERA SYSTEM DESIGN

The unique design feature of the Seagle-1was described in this section.. The design feature was based upon customer demanding a thermal imaging system with high sensitivity in a single compact package. The package outline was shown in Figure 1. The electrical power dissipation within the system is nominally 26 Watts when operating at 23℃ ambient. The ruggedized housing was constructed by using aluminum alloy. Integral hard mount surfaces for the printed circuit boards and cryocooler/detector assembly provide effective heat sinking via conduction. No force convection cooling is required allowing the unit to be completely sealed and resistant to rain and moisture. All mechanical parts, including the lens assembly, were "O-ring" sealed and maintained at a positive pressure insid the case. The camera include the lens weight was

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less then 3.0kg. The imager includes the detector/cooler assembly 、 electronics subassemblies 、 F.L100 mm f/1.8 standard lens 、 2.5" LCD display assembly and housing components. This is significant because nonuniformity calibration values that are programmed at the factory and require no additional recalculation in the field,.This feature offers significant compact in space and power saving.

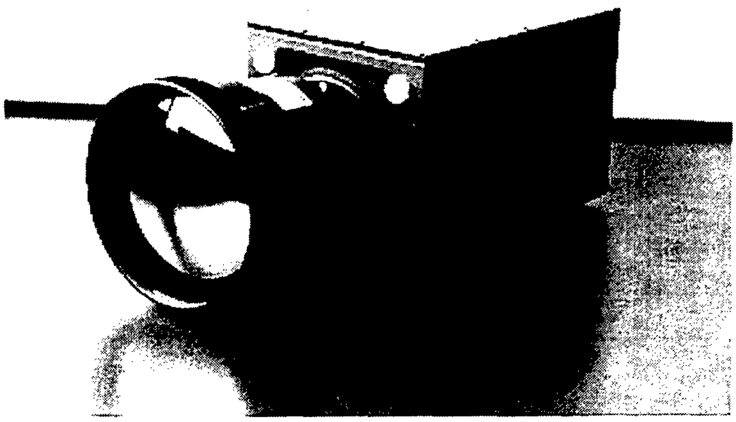


Figure 1. SEAGLE-1 camera system

2.1 System Features

System features are summarized as follows

Sensor Material	PtSi Schottky-Barrier IRCCD
Image Format	256Vx244H
Spectral range	3.4~5μm
Optics	4.6° X3.5° with 100mm lens, operation.....manual
Cold Shield	f 1.8 100% Efficient
Cooling method	Stirling-cycle cooler
Uniformity Calibration	2 point
Video format	RS-170, B&W
Weight	3.0 Kg
Power Supply	Rechargeable Battery or External AC
Data Output	12bit digital data,External Video connector

2.2 256x244 PtSi CCD Imager

The 256x244 element PtSi SB IRCCD detector is configured with monolithic focal plane array. The dimension of each pixel is $31.5\text{x}25\mu m^2$ and a fill factor greater than 36%. The double poly single metal process and 1.5μm design rule was used on these Pt/Si chips. The chip is monolithic silicon design using an interline transfer charge coupled device (CCD) readout architecture. The readout is carried out by vertical and horizontal CCD which is driven by four-phase clock pulses. The output preamplifier is a floating diffusion amplifier (FDA) with a two-stage source follower. The output transfer conversion gain of the FDA was greater than 2.0μV/electron. The sensorwas backside illuminated and sensitive to radiation in the 1-5μm wavelength band. The specifications of the focal plane array and measured performance were summa rized in Table 1.

Figure 2. was the PtSi chip configuration. The chip size and active image area were 9.4 x7.7 mm^2 and 8.1x6.1mm^2 respectively. The device is bonded in a 32-pin ceramic package with a hole in the center for backside illumination.

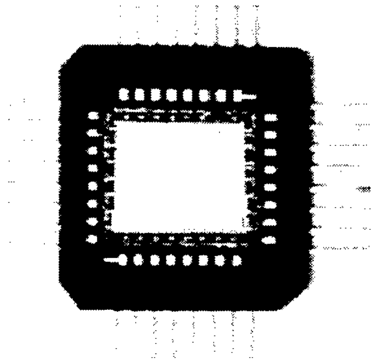


Figure 2. Photograph of 256x244 PtSi IRCCD sensor

Table 1. Focal plane Array Specification

Material	Platinum Silicide
Array Size	256 H x 244 V
Detector size	19.5 um x 17um
Pixel size	31.5um x 25um
Fill Factor	>36%
Infrared Band	MWIR
Architecture	Charge Coupled Device
VCCD & HCCD	4 Phase
Charge Capacity	1x10^6electrons per pixel
Charge Transfer Efficiency	>0.9998
Quantum Efficiency	>0.6 % at 4um

2.3 Optics

The optic system consist of a four-element , refractive ,100mm focal length, MWIR lenses, in conjunction with a silicon dewar window, 3.4um to 5um cold bandpass filter, and a F/1.8 cold shield.

2.4 Detector- Dewar Cooler Assembly

The crycooler-dewar assembly was a permantly evacuated dewar with an internal f/1.8 cold shield and cold filter cooled by a miniature integral 0.5 W Stirling cooler. In order to minimize size and power dissipation within the sensor assembly, an

Integrated Detector Cooler Assembly (IDCA) is utilized. In an IDCA packaging scheme, the focal plane array, cold shield and cold filter were attached directly to the crycooler expander. The IDCA packaging technique eliminates the significant thermal losses and thermal mass of a dewar inner stem. At the system level, the result is lower input power and faster cool down time for a given cooler. The miniature integral 0.5 W Stirling cycle cooler was the Model K-508A which manufactured by Ricor Ltd. The K508 model was the newest microcooler product offered by Ricor. The integration of the detector/dewar assembly was shown in Figure 3. Although these coolers utilize a rotary type compressor, it demonstrated a reliability of greater than 4000 hours. These coolers was suitable applied for portable/low power systems. The power efficiency and audible noise requirements were obviously extremely critical to hand held, battery operated imaging system, particularly for both military and low enforcement application.

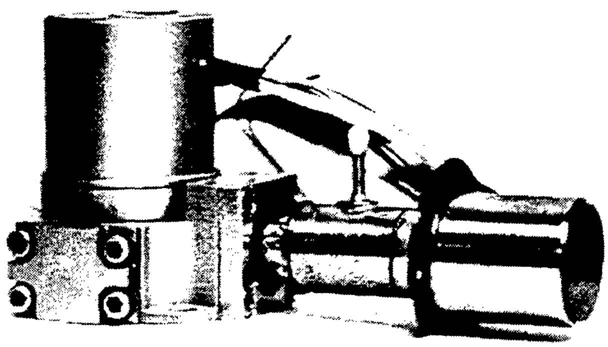


Figure 3. Integral Dewar/Cooler Assembly

2.5 Electronics

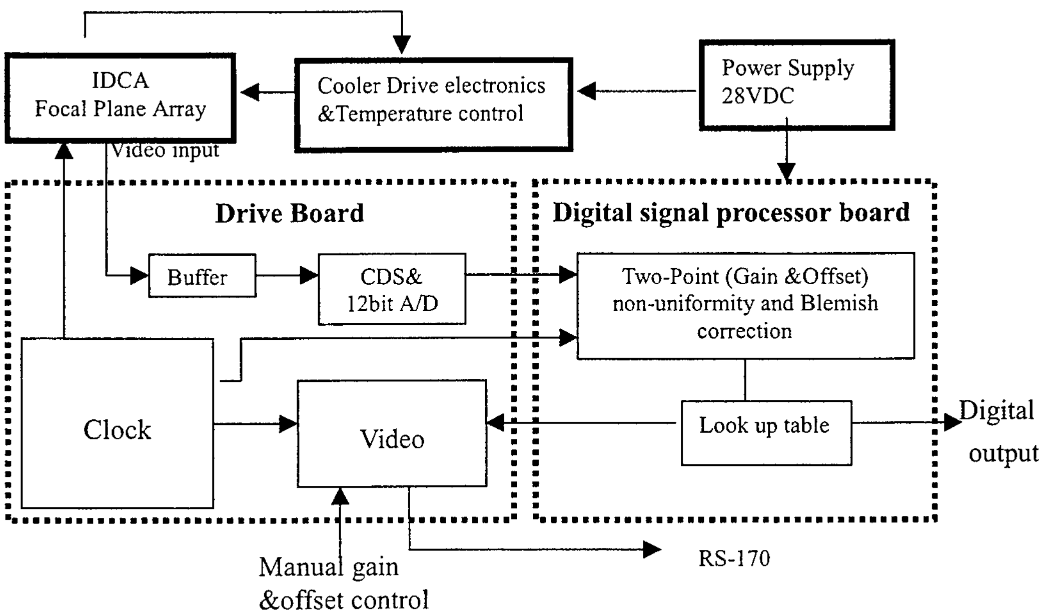
The electronics were design to accommodate the weight, power and functionality goals of Seagle-1. A generalized schematic of the electronics signal flow was shown in Figure 4. The major functions were implemented in two primary circuit boards. The first primary circuit board was the drive and power supply board. It contains circuitry to operate the FPA and generate NTSC video timing and signal levels. This drive board also apply contrast and brightness adjustments. The signal was digitized into 12 bit digital video signals which sent to digital signal processing (DSP) board. The power supply circuit received a 28 DCV input and produce all the necessary voltages for the electronics. It also supplies power to the 2.5" LCD display monitor.

The second primary circuit board was the data board. It contains circuitry for nonuniformity correction. The correction method used here is a two-point correction scheme. The gain and offset for each pixel are measured in lab and stored in EPROM. This approach required no additional recalculation in field operation, and offered significant saving in space and power. After the correction, the processed digital video is sent back to digitizer board again and was converted to standard RS-170 TV compatible signal.

The external controls of the camera contained an on/off switch, a video output connector for a remote video monitor and contrast and brightness control knobs.

The battery provided with the system was a nickel-metal-hydride battery of 3000mAhr capacity that will operate the camera for about 2 hours. An AC adapter was also an option part of the camera.

Figure 4. Camera Processor Block diagram



3. CAMERA PERFORMANCE

We measured the Seagle-1camera performance, which include Noise Equivalent Temperature Difference (NETD), Minimum Resolvable Temperature Difference (MRTD), and system dynamic range. The infrared camera performance was measured by using SIRA image test console. The field test result for human beings and track were shown on Fig.5.

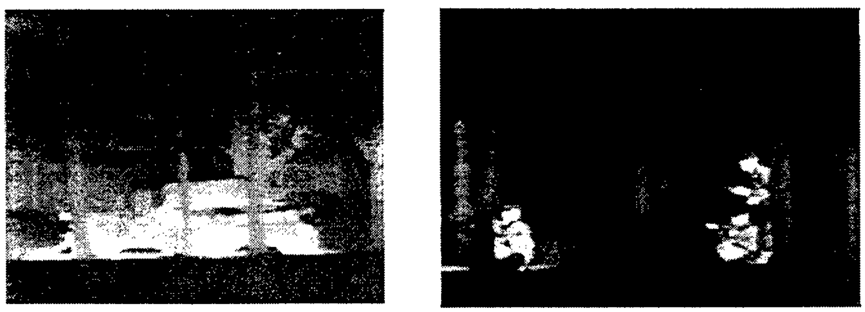


Fig.5. Field test data of track and 3 solders. Time:20:00. Dec.1999

3.1 NETD

The NETD of those camera have measured from the signal swing level to a temperature difference (△T=+-5℃) and noise level. The following is the measurement result of NETD and condition of measurement. The measured NETD of Seaeagle-1 at 25 C was 0.067 C with a F/1.8, 100 mm lens.

3.2 MRTD

The MRTD is defined as the minimum temperature difference of the 4-bar target, which is resolvable at each spatial frequency. We measured the horizontal and vertical MRTD in standard condition (with 100mm lens and at 23C background temperature). The horizontal MRTD of the Seaeagle-1 is 0.278 C and the vertical MRTD is 0.299 C both at 1.66 cycles/mRad (Nyquist frequency of Seaeagle-1). The horizontal MRTD of SeaEagle-1 is 0.092 C and the vertical MRTD is 0.105 C both at 0.804 cycles/mRad (about 1/2 Nyquist frequency). These results showing that the Seaeagle-1 has well consistent with original design. The MRTD test result was shown in Fig. 6.

3.3 Dynamic range (D/R)

The Dynamic range (D/R) is defined as the ratio of the temperature window to NETD. i.e. D/R = 20*log(Temp_window/NETD). The SeaEagle-1 thermal imager has a fixed gain for special usage. The temperature window is set to 16 Kelvin and D/R is 50 dB.

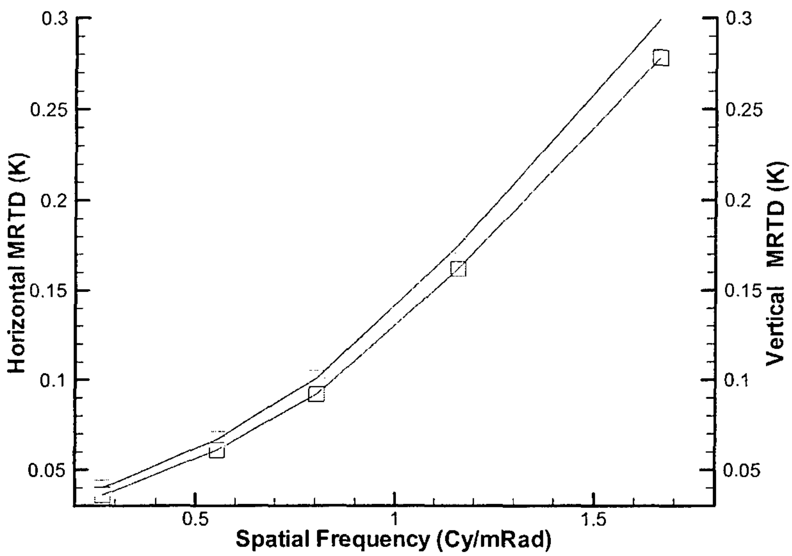


Fig.6. Seagle-1 horizontal and vertical MRTD

The summary of camera performance was shown in table 2

Table 2. Summary of the Seaeagle-1 thermal imager performances

Item	Performance
Model / Type	Sea Eagle-1
Detector	PtSi 256x244
NETD	0.067 C at 300K F/1.8
Horizontal MRTD	0.092 C at 0.5 Nyquist
Field of View	4.5^{o} 100 mm lens
Analog video output	RS-170 (BNC) 3" LCD
Cooling method	Stirling-cyclc cooler
Dimension (WxLxH)	108mm x 185mm x 116 mm without Lens
Weight	3 kg

4. Conclusion:

The Seagle-1 infrared thermal image camera based on CSIST's PtSi SBFPA has been developed. The performance of the system was in consistent with the original design. This system was qualified and field tested. This compact system could be applied in surveillance and law enforcement.

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